

Micro-Scale Distribution of Trace Elements in a High Boron Soil from Kern County, California

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INTRODUCTION

Determining structure and distribution of trace elements in soil is critical for the understanding of trace element cycling in soil systems and thus for proper soil management. This is particularly important in soils containing high levels of potentially toxic trace elements, as can be found in the San Joaquin Valley. Although high levels of B and its corresponding toxicity in some soils has been documented for many years, not much is known about its solid phase speciation and associations in these soils. This study aimed to gain a greater understanding of both the mineralogy and trace element speciation/associations and distribution in a salty, high boron soil found in the San Joaquin Valley through the use of microprobe x-ray fluorescence (μ -XRF) and Fourier transformed infrared (μ -FTIR) spectroscopy. Even though μ -XRF and μ -FTIR can not directly detect B, valuable information about important elements associated with B and possible mineralogical forms may be determined. Direct micro-level B determinations will be by other methods.

MATERIALS AND METHODS

Soil samples from a Lethent series soil located in Kern County, CA were taken from various horizons. The soil contained very high levels of soluble salts and B (as high as 70 mg B L^{-1} soluble and 500 mg kg^{-1} soil total). White deposits were noted throughout the soil profile.

The soil pedes were air dried at 35°C and impregnated with LR White high grade resin under a vacuum in order to retain soil aggregate structure. The resin was hardened by heating samples at 60°C for 48 hours. The hardened samples were cut into thin sections (0.1-0.2 cm thick) using a diamond edged saw and polished to ensure a smooth surface. The thin sections were then analyzed using μ -XRF on Beamline 10.3.1 and μ -FTIR spectroscopy on Beamline 1.4.3. Transects scanning across white deposits were collected. The resulting μ -XRF data were corrected for background and normalized to a NIST standard with known elemental concentrations.

Additional FTIR scans were collected on various known soil minerals, including the B minerals colemanite, kernite and borax. In addition, the minerals gibbsite and illite were treated with 20 mg L^{-1} B at pH 9, and scans of these minerals both with and without sorbed B were collected.

RESULTS AND DISCUSSION

X-ray Fluorescence Microprobe

The spatial distributions of Ca, S, P, Fe, As, and Si are shown in Figure 1. Two distinct regions are apparent, a region of high Fe and Si located at 0 - $800 \mu\text{m}$, which can be attributed to the bulk soil, and a region of high Ca and S located at 800 - $2500 \mu\text{m}$ (white deposit). Most of the trace

elements (Zn, Cr, Ti, K, and Mn) were associated primarily with the fine-grained matrix and were not present in the Ca-S region (data not shown). However, P was associated mainly with the Ca-S region. Judging from the high levels of Ca and S, this white deposit is most likely gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The phosphate is probably present as a Ca phosphate mineral or some sorbed form. There was no strong association of As with either the bulk soil or the Ca-S region, although slightly higher As concentrations may be present in the bulk soil. There were also some hot spots of certain elements. For instance, there was a K spike in the Ca-S region (data not shown) and a Si spike which occurred near the soil matrix/Ca-S boundary. There appears to be an association of As with the Si spike. This was also observed in another sample. However, upon closer examination we found the Si-As association was not perfect and it is more likely As is associated with minor amounts of Fe.

The analysis of other white deposits found throughout the soil revealed similar trends and regions of high Fe and Si in bulk soil and high Ca-S-P in white deposits. However, a white region which appeared to have low levels of all elements analyzed was also observed. This region may represent a non-Ca carbonate or halide mineral, although the possibility of a micro-pore space can not be ruled out. Although B can not be detected by this method the results clearly show that we can differentiate regions in the soil matrix in which B may be associated with the solid phase.

Fourier Transformed Infrared Spectroscopy

FTIR scans of soil thin sections are currently being analyzed. Preliminary analysis shows distinct differences between spectra from the soil matrix and white deposits (Figure 2), however the

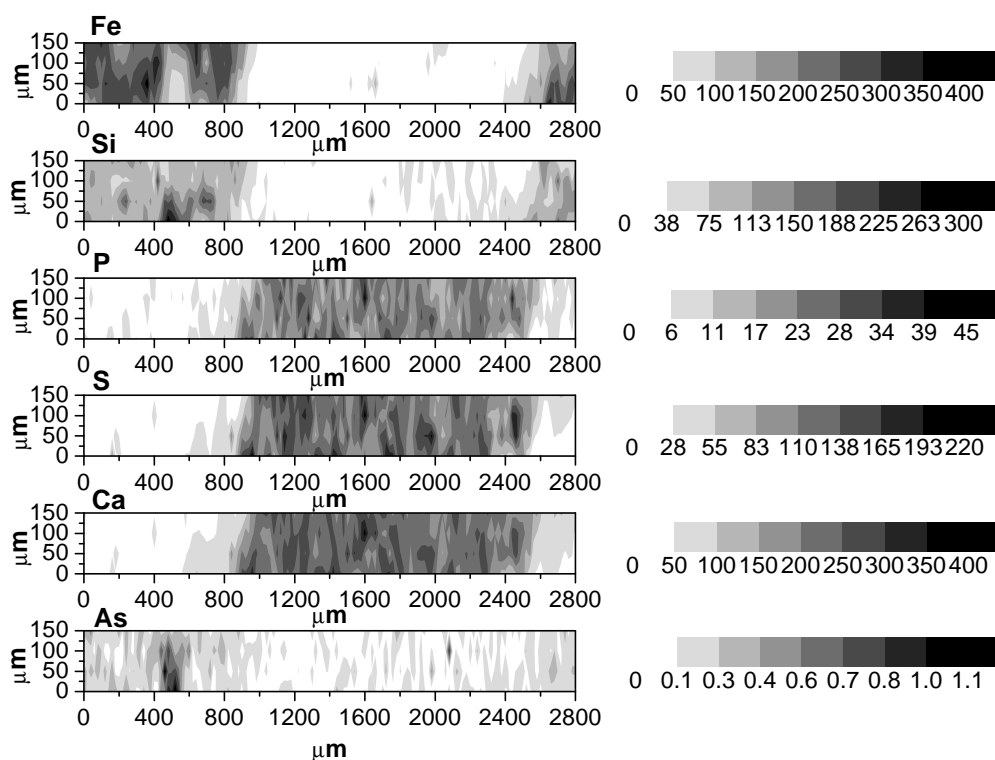


Figure 1. Spatial distributions of various elements around a white deposit. Concentrations are in units of $\mu\text{g}/\text{cm}^2$. The y-axis was expanded so that patterns could be seen more clearly.

epoxy resin used to harden soil sections swamps much of the signal from these samples and further analysis of spectra is required to extract the non-resin signal from this data. The FTIR spectra of various B containing and other soil minerals were obtained and exhibit distinct identifiable features which will assist in the analysis of soil spectra. The spectra from gibbsite with and without sorbed B appear to be the same. The illite spectra with and without B also appear to be the same, with the exception of the appearance of an additional peak in the O-H stretching region in the B treated sample.

The μ -XRF microprobe at Beamline 10.3.1 allowed us to collect information on the spatial distribution of elements in intact soil aggregates on a micron scale. This information is very useful for both inferring mineral compositions and understanding trace element associations with various mineral fractions of soil. Interpretation and analysis of the μ -FTIR data is complex due to the heterogeneous nature of soil and the presence of hardening resin, and analysis of this data is ongoing. The use of μ -FTIR (Beamline 1.4.3) is promising for mineral identification on a micron scale and the investigation of B structures and associations in soil and treated minerals.

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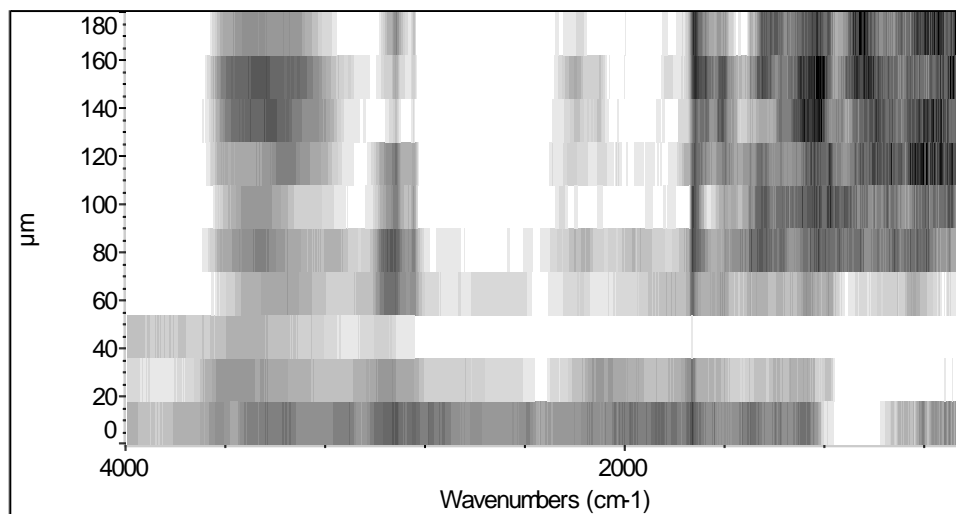


Figure 2. Contour map showing spectral intensities in the 4000 to 400 cm^{-1} spectral range. The y-axis shows the position along a scan line from the soil matrix (0-60 μm) to a white deposit (80-180 μm). The darkest lines represent the highest spectral intensity.

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